

Harmful Algal Blooms and Cyanotoxins in Metropolitan Water District's Reservoirs

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The Metropolitan Water District of Southern California (MWDSC) supplies drinking water to about 18 million people in six counties in the coastal plain of southern California. MWDSC is composed of 26 member agencies, which are cities or regional water agencies. Its two sources of water are the Colorado River and water from northern California, called State Project Water (SPW), delivered through the California Aqueduct. MWDSC operates three reservoirs in Riverside County: Lake Mathews, Lake Skinner and Diamond Valley Lake. The former is the terminal reservoir of the Colorado River Aqueduct; the other two reservoirs are supplied with a blend of the two waters. In addition, the state Department of Water Resources owns and operates Silverwood Lake, Lake Perris and Castaic Lake, three combined drinking water and recreational lakes that receive State Project water. Metropolitan regularly receives water from Castaic Lake (northwest of Los Angeles) and Silverwood (in the San Bernardino Mountains), and occasionally also uses water from Lake Perris.

Metropolitan has a long history of algal problems, in the form of planktonic blooms and benthic proliferations. The main concern is taste and odor, specifically the compounds geosmin and 2-methylisoborneol (MIB), which impart a disagreeable flavor to the water and cannot be easily removed by conventional treatment methods. All of the reservoirs listed above have experienced algal blooms of one kind or another, including in some cases known toxigenic species. In addition, Lakes Mathews, Skinner, Perris, and Diamond Valley have developed benthic mats that have resulted in severe off-flavor problems.

In 1996, an AWWARF project on the occurrence of algal toxins in raw and treated waters in the United States and Canada was initiated, perhaps the first serious effort by the U.S. drinking water industry to assess the extent of the problem. This study showed that at least one type of cyanotoxin, the microcystins, can be found in many water sources in the U.S., sometimes even in treated waters, albeit at low concentrations (Carmichael, 2001). Metropolitan was a participating utility in this study, and the results indicated that microcystins could be found in cyanobacterial bloom material from various source-water reservoirs, and in the corresponding plant influents and in some cases even the effluents. However, the levels were generally low, and no further monitoring was done on our system until the summer of 2001, when there was a severe bloom of *Aphanizomenon* in Silverwood Lake and of *Microcystis* in Lake Skinner. Samples of bloom material were sent to the laboratory of Dr. Gregory Boyer at SUNY in Syracuse, NY. Two of the *Microcystis* samples had relatively high microcystin levels, while the *Aphanizomenon* samples had no significant levels of any of the tested toxins. These results, though not surprising (the bloom samples giving the highest results were fairly concentrated samples), prompted concern regarding the need for more regular monitoring of these compounds in the water. In view of the likelihood that cyanotoxin monitoring will be required under the UCMR, this concern would appear justified.

The results of the 2001 samples prompted the development of a cyanotoxin monitoring program at Metropolitan's Water Quality Laboratory. This monitoring utilized two ELISA test kits for microcystin (Envirologix Inc., Portland, ME), a plate kit and a tube kit. The former was used primarily for testing water samples, while the latter was used for screening bloom samples, benthic algal samples and cultures. In addition, many samples were sent to Dr. Boyer's lab under a contract with Metropolitan. This was for confirmation of microcystin and identification of the variant. Also, since we are unable to test for toxins other than microcystin, the contract lab was needed to test for these other toxins, e.g., cylindrospermopsin and anatoxin-a.

We now have two years' worth of data on cyanotoxins in our system. Microcystin has been found in varying concentrations in surface water from all six reservoirs that were sampled. The concentrations ranged from 0.116 µg/L to 55.27 µg/L, although most of the samples were closer to the lower end of this range. The highest values were all from samples of concentrated bloom material, usually dominated by *Microcystis*. However, the majority of the water samples tested had no detectable microcystin or were just barely over the detection limit of 0.147 µg/L. The WHO guideline for drinking water is 1.0 µg/L.

In the summer of 2003, we also began testing benthic algal material from the shallows of various reservoirs, and in the process of this testing found that a cyanobacterium that is very common in three of those reservoirs produces microcystin. Eighteen isolates of this organism (a *Phormidium* sp.) were sent to Dr. Boyer's lab for verification, quantitation and identification of the toxin, and twelve of them were confirmed as strong microcystin producers. The variant was microcystin-LR in most cases. In addition, seven sediment samples were analyzed, and some of them had relatively high concentrations of microcystin, the highest being 287.95 µg/g dry wt, and the lowest 1.23 µg/g dry wt. A paper on this work is in the process of being reviewed by two collaborators in preparation for submission to a journal.

The benthic microcystin producer is the only source of the toxin found to date in our system other than *Microcystis*, and may be significant in being a more permanent "inhabitant" than the more transient and seasonal planktonic sources. Moreover, this organism grows intermingled with cyanobacteria that produce odorous compounds like geosmin and 2-methylisoborneol. These benthic proliferations are periodically treated with copper sulfate to control taste-and-odor problems. Application of the algicide to these organisms can in theory release the microcystin into the water, potentially affecting water supplied to several treatment plants.

No other toxins have been found in significant levels in Metropolitan's waters. Blooms of *Anabaena flos-aquae* and *A. lemmermanii* have been tested for anatoxin (at Dr. Boyer's lab), but all were negative. However, an *Anabaena* isolated from Castaic Lake in 1999 was found to produce anatoxin-a.

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